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**MTF ANALYSIS OF LANDSAT-4 THEMATIC MAPPER**

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## **MTF ANALYSIS OF LANDSAT-4 THEMATIC MAPPER**

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A research program to measure the Landsat-4 Thematic Mapper (TM) modulation transfer function (MTF) is described. The research is being conducted by the University of Arizona and NASA/Ames Research Center under the contract "An Investigation of Several Aspects of Landsat-D Data Quality" (Robert C. Wrigley, Principal Investigator).

Measurement of a satellite sensor's MTF requires the use of a calibrated ground target, i.e. the spatial radiance distribution of the target must be known to a resolution at least four to five times greater than that of the system under test. Any radiance structure smaller than this will have a small effect on the calculated MTF. Calibration of the target requires either the use of man-made special purpose targets with known properties, e.g. a small reflective mirror or a dark-light linear pattern such as line or edge, or use of relatively high resolution underflight imagery to calibrate an arbitrary ground scene. Both approaches will be used in this program; in addition a technique that utilizes an analytical model for the scene spatial frequency power spectrum will be investigated as an alternative to calibration of the scene. The test sites and analysis techniques to be used in this program are described in this paper.

## MTF ANALYSIS OF LANDSAT-4 THEMATIC MAPPER

### INTRODUCTION

Measurement of a satellite sensor's MTF requires the use of a calibrated ground target, i.e. the spatial radiance distribution of the target must be known to a resolution at least four to five times greater than that of the system under test. Any radiance structure smaller than this will have a small effect on the calculated MTF. Calibration of the target requires either the use of man-made special purpose targets with known properties, e.g. a small reflective mirror or a dark-light linear pattern such as line or edge, or use of relatively high resolution underflight imagery to calibrate an arbitrary ground scene. Both approaches will be used in this program; in addition a technique that utilizes an analytical model for the scene spatial frequency power spectrum will be investigated as an alternative to calibration of the scene.

### TM SYSTEM CHARACTERISTICS

The characteristics of digital scanning sensors such as the TM influence the selection of targets-of-opportunity or the design of special purpose targets for MTF measurement. The three most important sensor characteristics are:

#### Two-dimensional performance

The sampling and signal processing characteristics of the TM are different along-scan and across-scan (along-track). Thus, the MTF is at least bi-directional and therefore requires a two-dimensional target for measurement.

#### Sampled imagery

The TM produces sampled, digital imagery. The impact of this is that the relative sub-pixel location of the pixel (sample) grid and the scene affects the quality of the imagery. This effect, called sample-scene phase, has been analyzed in one-dimension by Park and Schowengerdt (1982).

#### Multispectral imagery

Target reflectance characteristics may vary from band-to-band causing a change in target contrast. Furthermore there may be small-scale spatial variations in reflectance that change from band-to-band.

The following conclusions about MTF target characteristics may be drawn from the above observations:

- (1) The MTF should be measured in at least two directions, along- and across-scan.
- (2) The sample-scene phase effect must be accounted for in MTF analysis. The most direct approach would be ensemble averaging over the range of possible phases.
- (3) The spectral and spatial characteristics of any MTF target should be measured.

## MTF MEASUREMENT TECHNIQUES

There are several ways to measure a satellite system's MTF. Absolute approaches require the use of known, special-purpose targets or independent calibration of arbitrary targets. Relative approaches permit only comparison of the quality of different data sets, for example between detectors. In all cases it is desirable to use targets with high spatial frequency content, i.e. edges, lines, points, etc. The techniques to be used in this project are:

### Two-image analysis

This approach was originally applied to MTF measurement of the Landsat-1 MSS (Schowengerdt, 1976). It requires a near-simultaneous aircraft underflight with a sensor similar to that in the satellite. The aircraft imagery provides a high resolution calibration of an arbitrary scene in the same spectral bands as those of the satellite sensor.

### Special targets

Candidate targets are high contrast edges, lines, combs (periodic bars), and point sources. Comb targets have signal-to-noise advantages at certain spatial frequencies. For all of these targets several parameters must be balanced to obtain a suitable target, for example the shape, contrast, size and material characteristics. The image of an edge, line, or point source is the Edge Spread Function (ESF), Line Spread Function (LSF) or Point Spread Function (PSF), respectively. Each is related in some manner to the MTF via Fourier transformation. For example, the magnitude of the 2-D Fourier transform of the PSF is the 2-D MTF and the magnitude of the 1-D Fourier transform of the LSF is a 1-D cross section of the 2-D MTF at a given azimuth angle. Furthermore the LSF is the derivative of the ESF.

### Power spectrum analysis

The ensemble average of spatial frequency content for a statistical sample of image data is called the power spectrum. It may be used to compare relative data quality from detector-to-detector or between forward and reverse scans without calibrating the absolute spatial frequency content of the data.

## RESEARCH PLANS

We plan to utilize all of the above techniques in this program to measure the TM MTF. Specifically the following is planned:

- (1) Three TM/underflight acquisitions in the San Francisco area. The two-image analysis technique will be used on these data to measure TM MTF from three scene dates over a period of about one year. The NS001 scanner will likely be used in the aircraft underflights.
- (2) Two or three TM acquisitions of the White Sands National Monument area will be used to image the black-on-white runway markers at the Shuttle land site (Northrup Strip). These markers are in the subpixel-to-pixel size range and are therefore possibly suitable for MTF measurement. In addition the feasibility of creating new, special-purpose targets in a similar manner is being pursued with the Army at the White Sands Missile Range. MTF measurements in the White Sands area have the advantage of collaboration with Dr. P. N. Slater and his radiometric measurement activities there. These data will be valuable for characterization of the atmospheric effect on MTF measurement.
- (3) Targets-of-opportunity such as bridges, highways, etc. will be analyzed as available. Work has begun on analysis of the Washington DC scene acquired on November 2, 1982 (ID# 4020915140) in both the A and P formats to evaluate the relative image quality of each. There are several bridges and roads in the scene that are candidate targets. In addition, deployment of several small, reflective mirrors (Evans, 1974) is anticipated in conjunction with the San Francisco acquisitions. These mirrors will represent high intensity point sources and consequently are ideal for MTF measurements, if no sensor saturation occurs.

## ACKNOWLEDGEMENTS

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